NASA TECH BRIEF

Goddard Space Flight Center

Stabilizing a Gaseous Optical Laser

The problem:

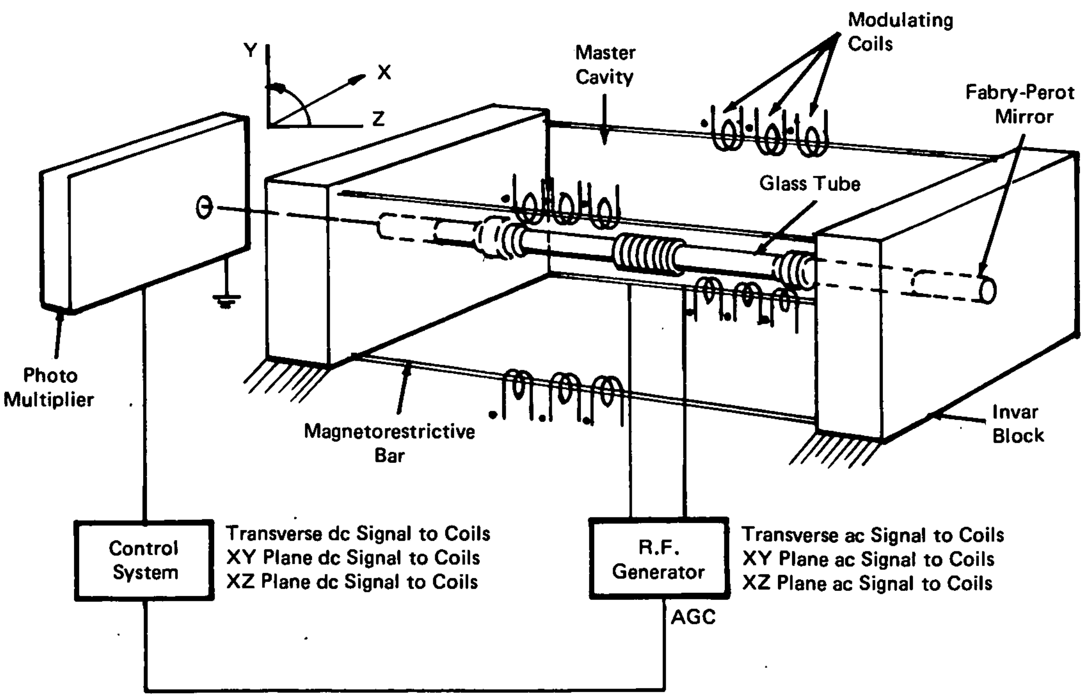
Optical lasers are subject to a certain amount of frequency fluctuation. Because one of the primary uses of these lasers is as a frequency standard, every effort is made to remove any such variation. This is normally attempted by placing the laser in special laboratory surroundings that have extensive thermal and acoustical insulation.

The solution:

The frequency of a gaseous optical laser can be stabilized by sinusoidally modulating the geometry of the cavity.

How it's done:

In the near infrared and visible portion of the spectrum, the stability of a gaseous, atomic laser depends primarily on the stability of the cavity length. Because the Doppler broadening of the atomic transition is significantly greater than that of the cavity resonance, the cavity Q (energy factor) is much greater than the atomic Q, and the laser frequency is proportional to the cavity length. The cavity, in this case, consists of a pair of Fabry-Perot mirrors. It has two resonant elements at approximately the same frequency causing its output vs. frequency characteristics to be similar to that of double tuned circuit.



Optical Laser and Control System

(continued overleaf)

By adjusting the ac excitation power of the laser so that the system operates at critical coupling, it is possible to keep the frequency stable for relatively long periods, up to fifteen minutes. At critical coupling, the output-power vs. cavity-length curve has first, second, and third derivatives equal to zero. The power and cavity length can be monitored and automatically adjusted to keep the system at critical coupling. To control the cavity geometry, the pair of mirrors in the cavity are sinusoidally modulated, in three orthogonal directions. The distance between the mirrors and the relative tilt angles in two perpendicular planes are modulated. The average separation of the mirrors is controlled by detecting the third harmonic of the low-frequency, sinusoidal modulation imposed on the laser beam by the varying mirror separation. The absence of a third harmonic corresponds to a zero third derivative of the output vs. cavity-length curve and indicates that the cavity is tuned.

The laser is stabilized at a power level corresponding to critical coupling by detecting the second harmonic of the mirror separation modulation. A zero second harmonic (and second derative) occurs only at critical coupling.

The first harmonic is related to the angular alignment of the mirrors. If the mirrors are not aligned, the output power is a function of their angular difference. Thus the first harmonic is used to derive signals to control the average mirror angles.

The laser stabilizing system is shown in the illustration. Fabry-Perot dielectric mirrors are mounted in two Invar blocks that are connected by four magnetorestrictive bars. Each bar has three coils to sinusoidally modulate the system. The coils are wound so that, current in one coil moves the mirrors transversely, the second rotates the mirrors in the XY plane, and the third rotates the mirrors in the XZ plane. Both ac and dc are supplied to the coils from the control system. The ac establishes the frequency, and the dc the average value.

The light from the laser is detected by a photomultiplier which generates an ac signal corresponding to the mirror modulation. This signal is returned to the control system. The control systems responds to the photomultiplier signals to adjust the cavity geometry for critical tuning.

Note:

No further documentation is available. Specific questions, however, may be directed to:

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Reference: TSP73-10517

Patent status:

This invention has been patented by NASA (U.S. Patent No. 3,517,328). Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to:

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